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Rust Converters

Authored By: Dario A. Emeric, Bryan Westich,
and Richard C. McNeil

Report Date: November 1987

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PREFACE

In 1980, an Inspector General's report indicated that 40 percent of fielded tactical vehicles (such as trucks, jeeps, trailers) belonging to the 25th Infantry Division, Western Command (WESTCOM), were inoperable mainly due to corrosion. At the request of and in conjunction with the Tank-Automotive Command (TACOM), coatings and corrosion specialists from Belvoir Research, Development, and Engineering (RD&E) Center's Materials, Fuels, and Lubricants Laboratory visited the 25th Infantry Division to survey the situation. Based on recommendations and technical guidance, WESTCOM undertook a corrosion repair and rustproofing program.

To supplement the war against corrosion, The Chemistry Research Group of the Materials, Fuels, and Lubricants Laboratory is currently undertaking a research and development effort to develop a rust converter suitable for military applications. The studies include determining rust inhibitor compatibility with MIL-C-62218, *"Corrosion preventative compounds, cold-application (for new and fielded motor vehicles and trailers)."*

In the evaluations contained in this report, rust converters/inhibitors were used to passivate a pre-corroded substrate. Phosphoric acid and tannic acid based rust converters chemically change the composition of the ferrous oxide to a ferric phosphate and a ferric tannate, respectively, forming an adherent substrate which may then be coated with a bituminous coating. The ensuing experiments compare the rust inhibitors' conversion of both field and laboratory pre-corrosion. The project's goal was to use laboratory and field evaluations to develop a rust converter that would withstand military environments.

The following test methods and standards were used in the rust converter testing:

American Society for Testing and Materials (ASTM) B 117, *"Standard method of salt spray (fog) testing"*

ASTM D 610, *"Standard method of evaluating degree of rusting of painted steel surfaces"*

ASTM D 714, *"Standard method of evaluating degree of blistering of paints"*

ASTM D 1654, *"Standard method for evaluation of painted or coated specimens subjected to corrosive environments"*

ASTM D 2247, *"Standard method for testing coated metal specimens at 100% relative humidity"*

ASTM D 3170, "Standard test method for chip resistance of coatings"

Federal Test Method Standard (FTMS) 6226, "Impact resistance (reverse)"

Steel Structures Painting Council, Surface Preparation, Specification No. 2 (SSPC-SP2),
"Hand Tool Cleaning"

Tests performed on the rust converters used the following equipment:

Harshaw Salt Fog Cabinet, Model #22, Harshaw Chemical Company

Humidity Chamber, Model #QCT - ADO, Q-Panel Company

Gravelometer, Model #QGR, Q-Panel Company

Cold-Temperature Chamber (cold box), Model # TM-35, B-M-A Inc.

Coatings Film Knife. Model #201, Pacific Scientific

G.E. Impact Tester, fabricated at the Belvoir Research, Development, and
Engineering Center according to FTMS 6226

The following two panels were used in testing:

Cold Rolled Steel Q-Panels, R-Type, 0.023" thickness, dull matte finish, 4" x 12"
and 3" x 6" size, Q-Panel Company, 26200 First Street, Cleveland, OH 44145

Galvanized Panels, minimum spangle T.R., heavy duty galvanized, clean treatment,
4" x 12" x 22" gauge; G-90, Parker Chemical Company, 32100 Stevenson Highway,
Madison Heights, MI 49256



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SECTION I. PANEL PREPARATION

Pre-corrosion of the panels was the first step in the preparation process. A corroded substrate must be present for the rust converter to react and form a passive layer preventing further corrosion. The panels were corroded in two different ways—in the laboratory and in the field. Laboratory pre-corrosion was performed in the Harshaw salt fog cabinets according to ASTM B 117, "*Standard method of salt spray (fog) testing.*" Mild and severe depths of pre-corrosion were created for testing:

	Mild pre-corrosion	Severe pre-corrosion
Cold rolled steel	24 hours	120 hours
Galvanized (G-90)	74 hours	144 hours

In the field, the pre-corrosion was performed by WESTCOM in Hawaii and Sub-Tropical Testing Service in Miami, Florida. The panels were oriented at a 45° angle from the horizontal facing south for a period of 1 year.

After the pre-corrosion process, the loose corrosion was removed according to Steel Structures Painting Council, Surface Preparation Specification No. 2 (SSPC-SP2). "*Hand Tool Cleaning.*" This step created an adherent surface for the rust converter to passivate, rather than converting a corrosion nodule which could easily be knocked off.

The rust converters were then applied according to the manufacturers' specifications. To establish uniformity, the following process was developed:

- Step 1. Wet panel.
- Step 2. Tilt panel to allow excess water—such as puddles—to run off.
- Step 3. Brush on first coat of rust converter.
- Step 4. Let panel dry for no less than 12 hours.
- Step 5. Rinse panel and repeat step 2.
- Step 6. Brush on second coat of rust converter.
- Step 7. Let panel dry for no less than 12 hours.

The panels were then topcoated with Tectyl 517 (MIL-C-62218 bituminous compound). The topcoat was drawn down to an 11 mil wet film thickness (WFT) and allowed to cure for 7 days to a 5 mil dry film thickness (DFT).

Unless otherwise specified, the following rust converters were evaluated in each test:

- Commercial #1 (phosphoric acid based)
- Commercial #2 (tannic acid based)
- Commercial #3 (tannic acid based with latex)
- Commercial #4 (tannic acid based with latex)

Pre-corroded panels converted with rust converter and topcoated with Tectyl 517 were evaluated along with Tectyl 517 directly over the pre-corroded panels as a control.

SECTION II. CYCLIC GRAVELOMETER/SALT SPRAY

Impact by the gravelometer was performed in accordance with ASTM D 3170, "Standard test method for chip resistance of coatings." After the panels were prepared and cured, they were placed in the cold temperature chamber and cooled to -30°F for 2 hours prior to testing. This temperature was 10° colder than the actual test temperature of -20°F. As specified in ASTM D 3170, the 10-second warm up period accounted for the time it took to remove a panel from the cold box and begin the gravelometer test. Once cooled, the upper half of the panels was impinged with 1 pint of gravel (between 3/8 and 5/8 inch in size) projected at a pressure of 70 ± 3 pounds per square inch (psi). The tops of the panels were then evaluated according to the rating specified in ASTM D 3170.

Next, the panels were placed in the Harshaw salt fog cabinet (ASTM B 117, "Standard method of salt spray (fog) testing") for a period of 500 hours. The panels rested on the racks with the impinged area at the bottom (Figure 1).

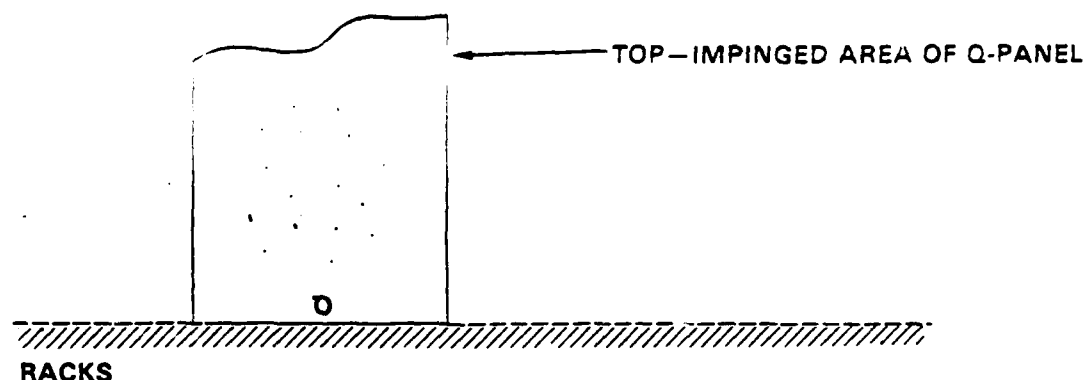


Figure 1. Rack in the Salt Spray Chamber

This prevented the rusting steel (exposed due to impingement) from draining down the panel. This also prevented moisture from penetrating underneath the topcoat and damaging the lower section of the panel. Upon completion of the salt fog exposure, the top and bottom of the panels were evaluated separately according to ASTM D 1654, "Standard method for evaluation of painted or coated specimens subjected to corrosive environments." After the evaluation, the panels were cooled again, then hit with gravel on the lower half. The final step in the testing was the ASTM D 3170 rating of the lower section.

Based on the ASTM D 1654 and D 3170 evaluations, the performance of the rust converters is shown below and graphed in Figures 2 and 3, respectively:

Laboratory pre-corroded panels

1. Commercial #2
2. Commercial #3
3. No rust converter
4. Commercial #1
5. Commercial #4

Fielded pre-corroded panels

1. No rust converter
2. Commercial #1
3. Commercial #2
4. Commercial #4
5. Commercial #3

ASTM D 1654 AND ASTM D 3170

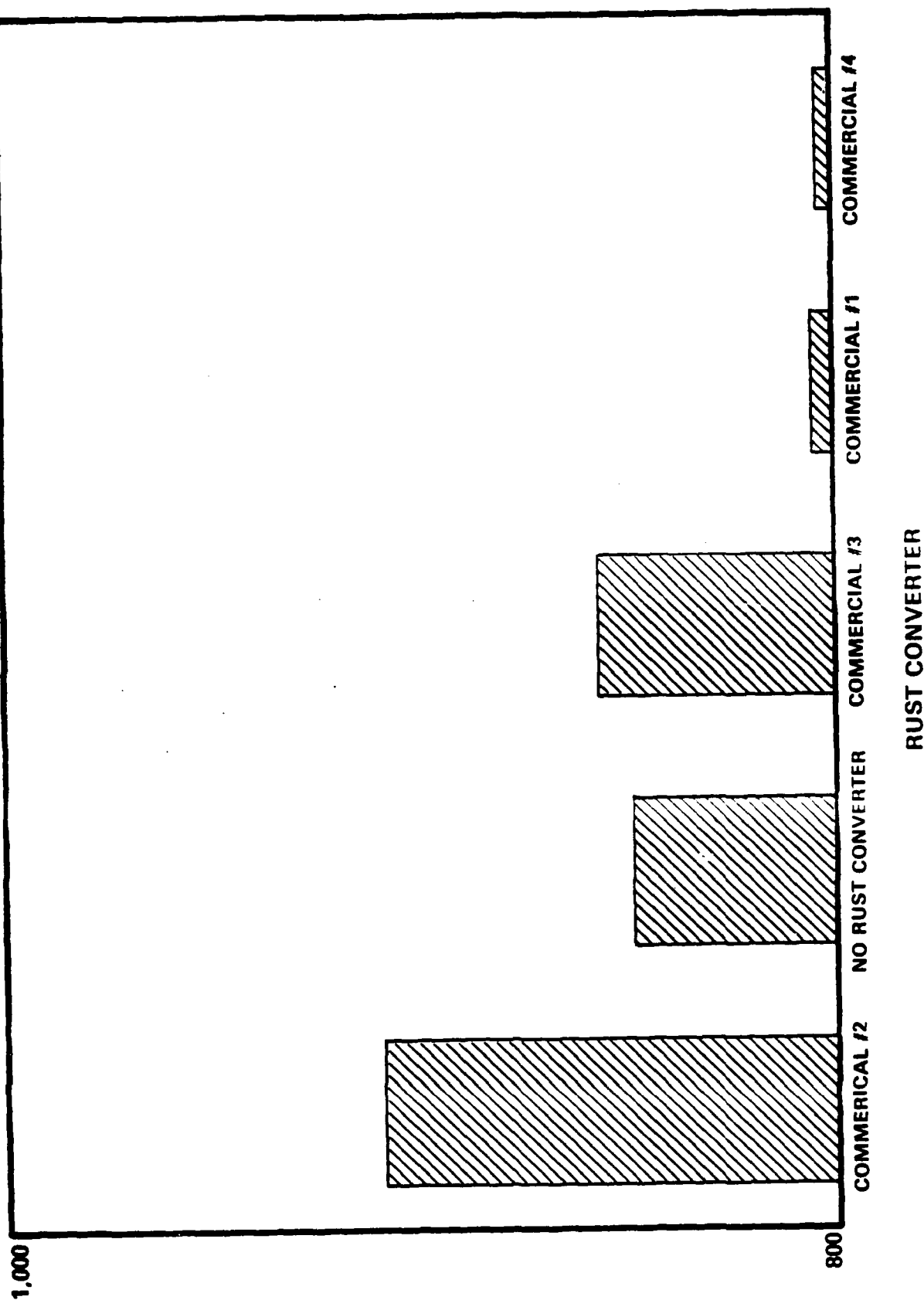
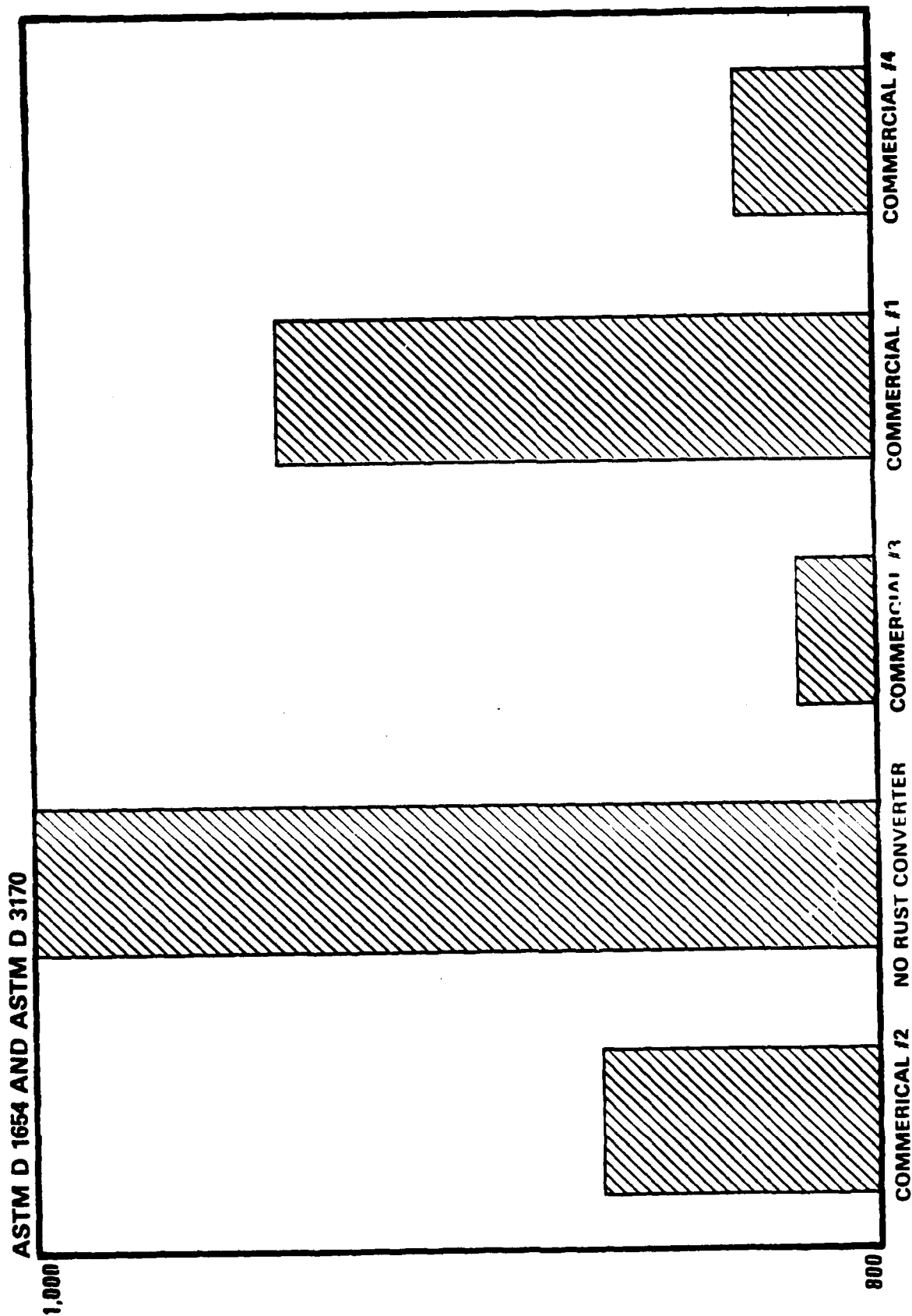


Figure 2. Cyclic Gravimeter/Salt Spray—Laboratory Pre-corrosion



RUST CONVERTER

Figure 3. Cyclic Gravelometer/Salt Spray -Field Pre-corrosion

It is easily noticeable that the cyclic gravelometer/salt spray testing produced different results when tested on field and salt spray pre-corroded panels. Neither the bituminous coating (no rust converter) nor any of the rust converters performed the same. Therefore, in this laboratory experiment, no correlation could be found between the laboratory pre-corroded panels and the field pre-corroded panels.

SECTION III. HUMIDITY

After the panels were prepared, they were placed in the humidity chamber and tested in accordance with ASTM D 2247, "*Standard method for testing coated metal specimens at 100% relative humidity.*" The test ran in cycles consisting of 8 hours of condensation at 40°C, followed by 4 hours of dry off at 60°C. Upon completion of the 500 hour test, the panels were evaluated according to ASTM D 714, "*Standard method of evaluating degree of blistering of paints,*" and ASTM D 1654, "*Standard method for evaluation of painted or coated specimens subjected to corrosive environments.*"

The performance of the rust converters based on these evaluations is shown below and graphed in Figures 4 and 5, respectively.

Laboratory pre-corroded panels

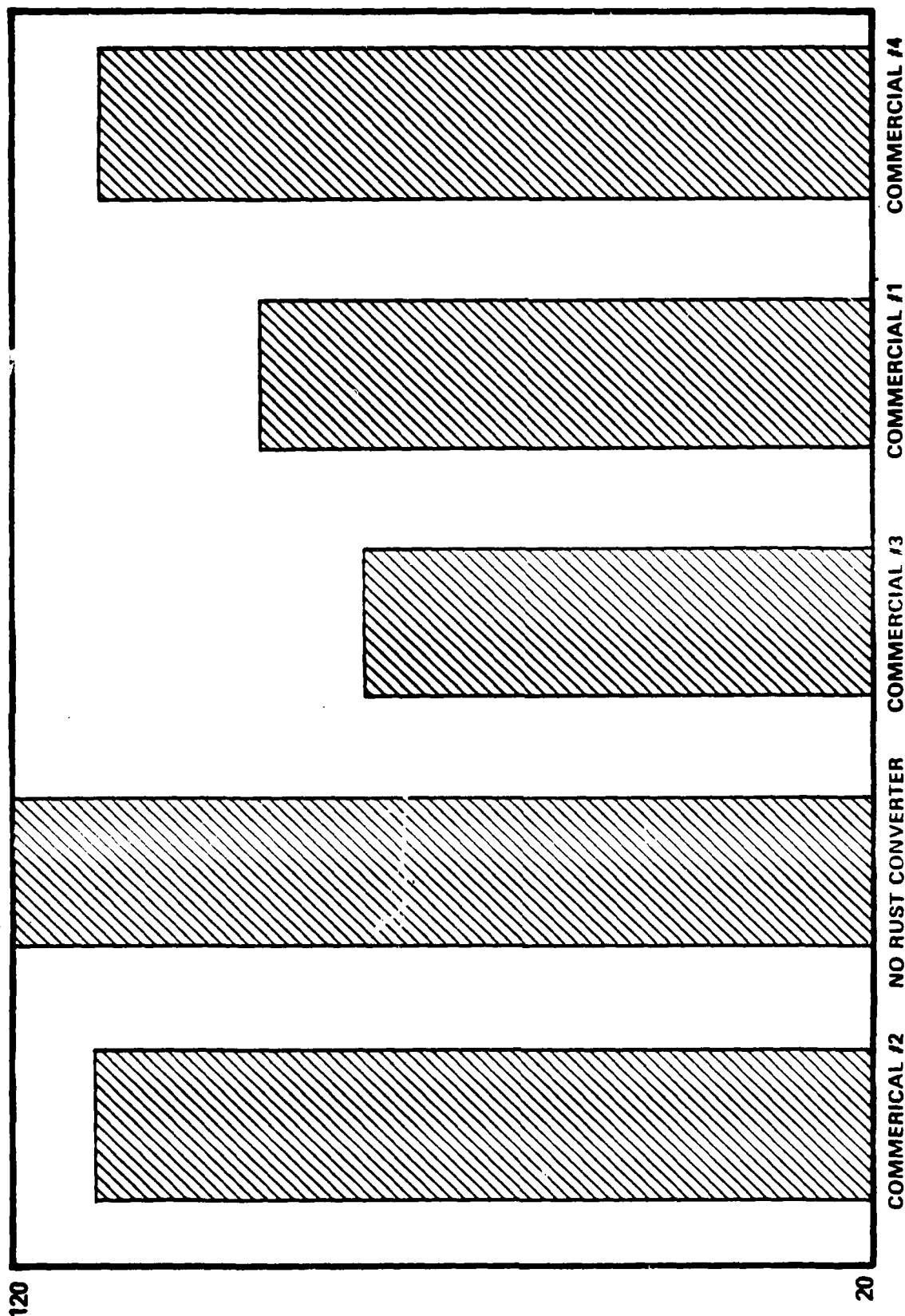
1. No rust converter
2. Commercial #2
3. Commercial #4
4. Commercial #1
5. Commercial #3

Fielded pre-corroded panels

1. No rust converter
- Commercial #4
3. Commercial #2
- Commercial #1
5. Commercial #3

Exposing both salt spray and field pre-corroded panels in the humidity chamber produced similar results. It is worth noting that the panels performed better when the intermediate step using the rust converter was eliminated, showing that the rust converters seem to promote accelerated corrosion, instead of retarding it.

ASTM D 714 AND ASTM D 1654



RUST CONVERTER

Figure 4. Humidity—Laboratory Pre-corrosion

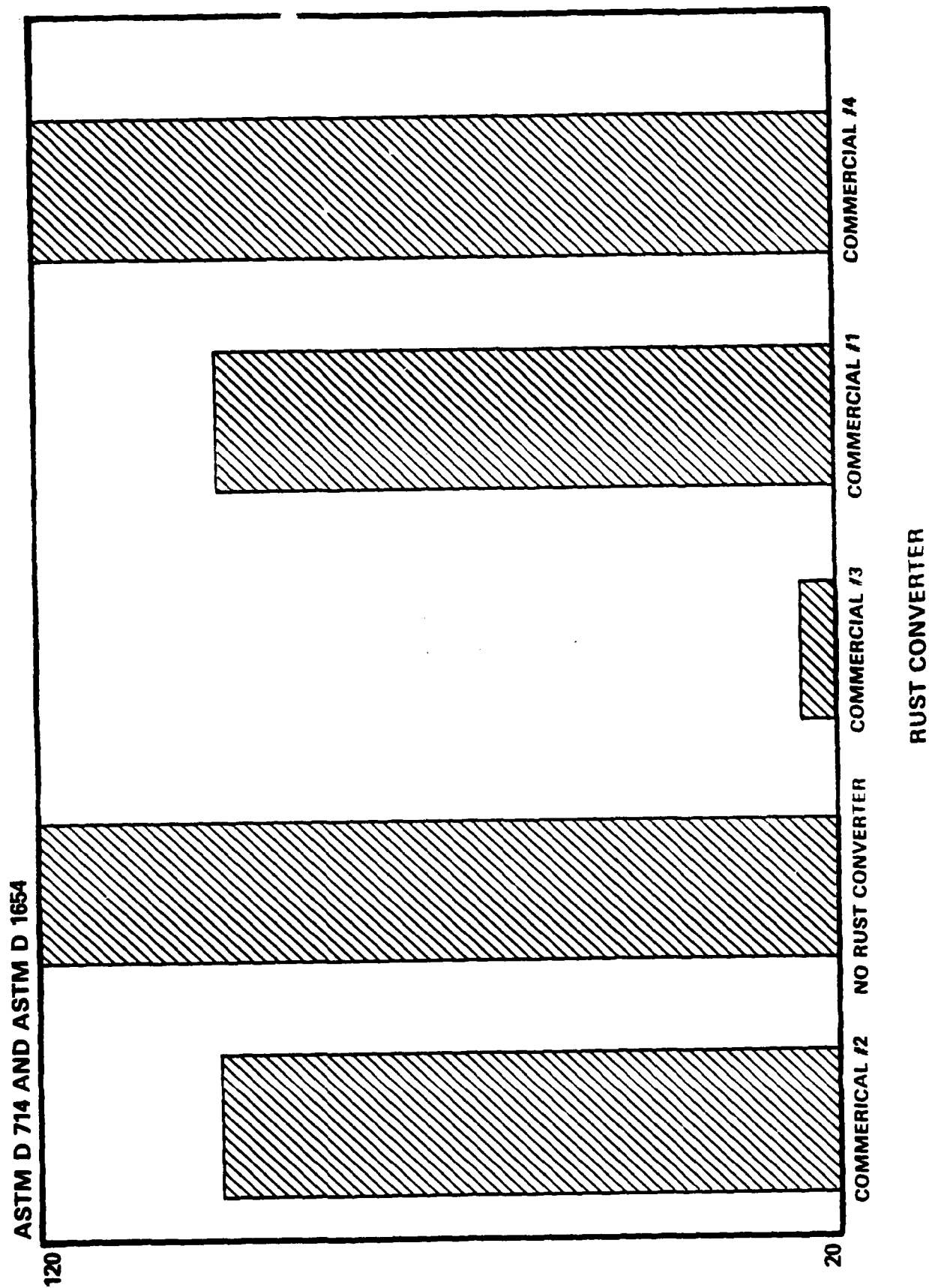


Figure 5. Humidity—Field Pre-corrosion

SECTION IV. REVERSE IMPACT RESISTANCE

Reverse impact resistance testing was carried out in accordance with Federal Test Method Standard (FTMS) 6226, "*Impact resistance (reverse)*." (NOTE: Subsequent to this testing, ASTM D 2794, "*Standard test method for resistance of organic coatings to the effects of rapid deformation (impact)*," replaced FTMS 6226.) Testing was performed using the G.E. Impact Tester. The impact weight shown in Figure 6 was dropped from a height of 2 feet.

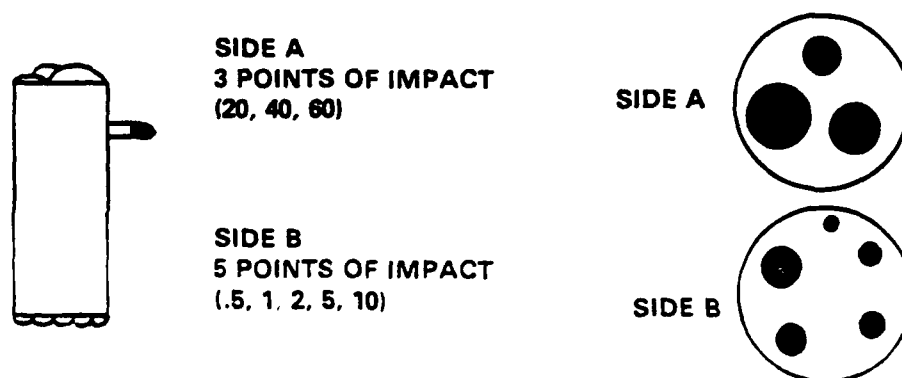


Figure 6. Impact Weight

Four trials were performed on prepared and cured panels. Each trial consisted of two hits—one from side A and one from side B of the impact weight. Trial #1 was performed in the upper left-hand corner of the panels at room temperature ($70^{\circ}\text{F} \pm 5^{\circ}\text{F}$). Upon test completion, each point of impact was evaluated on a pass/fail basis. Any sign of a crack in the coating or visible metal constituted a failing score.

Once trial #1 was completed, the panels were cooled to -30°F in the cold temperature chamber for at least 2 hours prior to conducting trial #2. This 10° decrease below the test temperature of -20°F allowed for the time it took to remove the panel from the chamber and perform the test. The two hits of trial #2 were then performed on the lower left-hand corner of the panel. Again, once testing was completed, each point of impact was evaluated on a pass/fail basis.

All test panels were then placed in the salt fog cabinets for a 500-hour duration in accordance with ASTM B 117, "*Standard method of salt spray (fog) testing*." Once removed from the salt fog cabinets, trial #3 and trial #4 were performed on the right-hand side of the panel. These tests were the same as trials #1 and #2, respectively, except they were performed after the salt spray exposure and on the opposite side of the panel.

Shown is a ranking of the rust converters based on the percentage of points passing the test. This data is graphed in Figures 7 and 8, respectively.

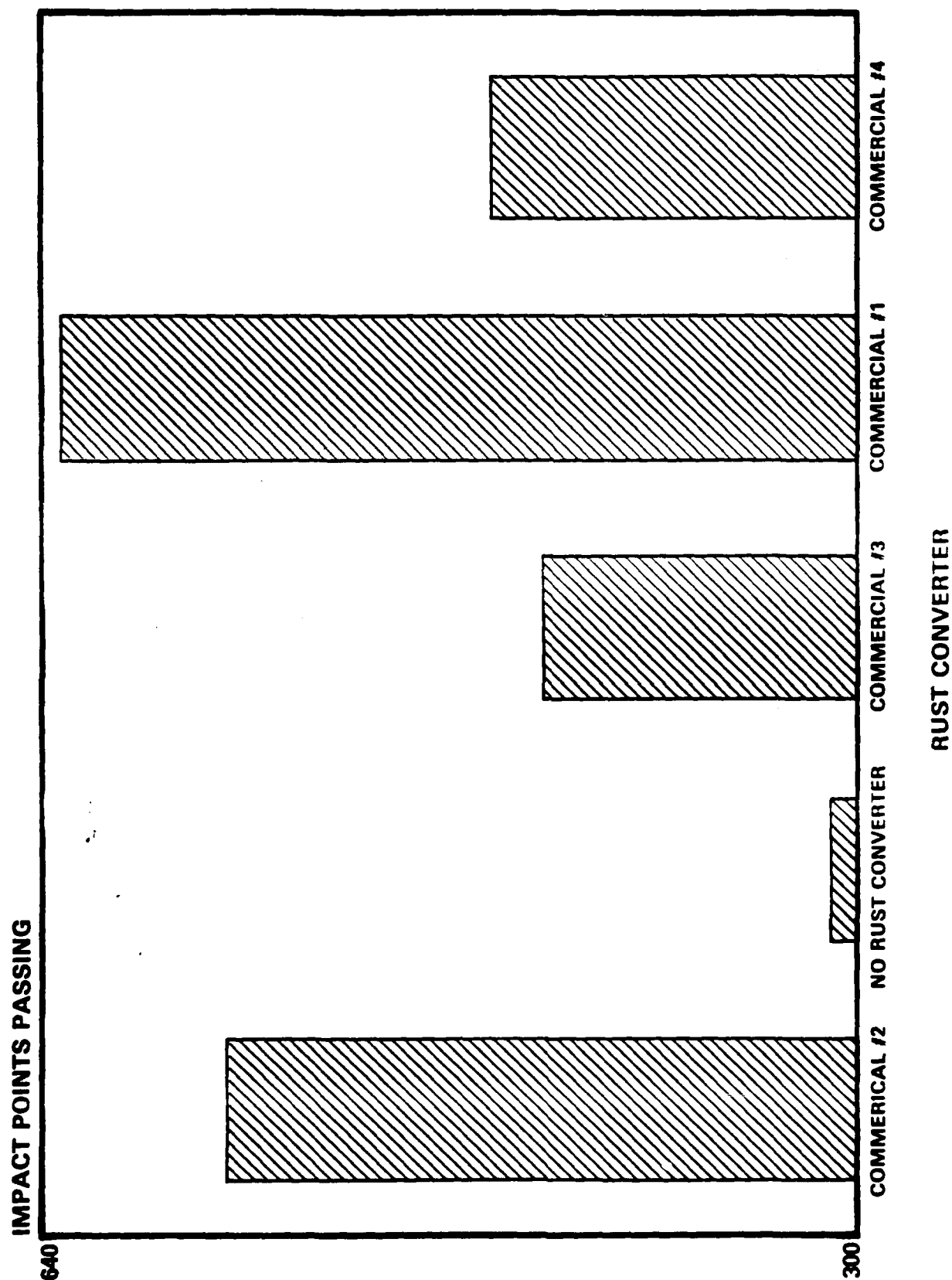


Figure 7. Reverse Impact Resistance—Laboratory Pre-corrosion

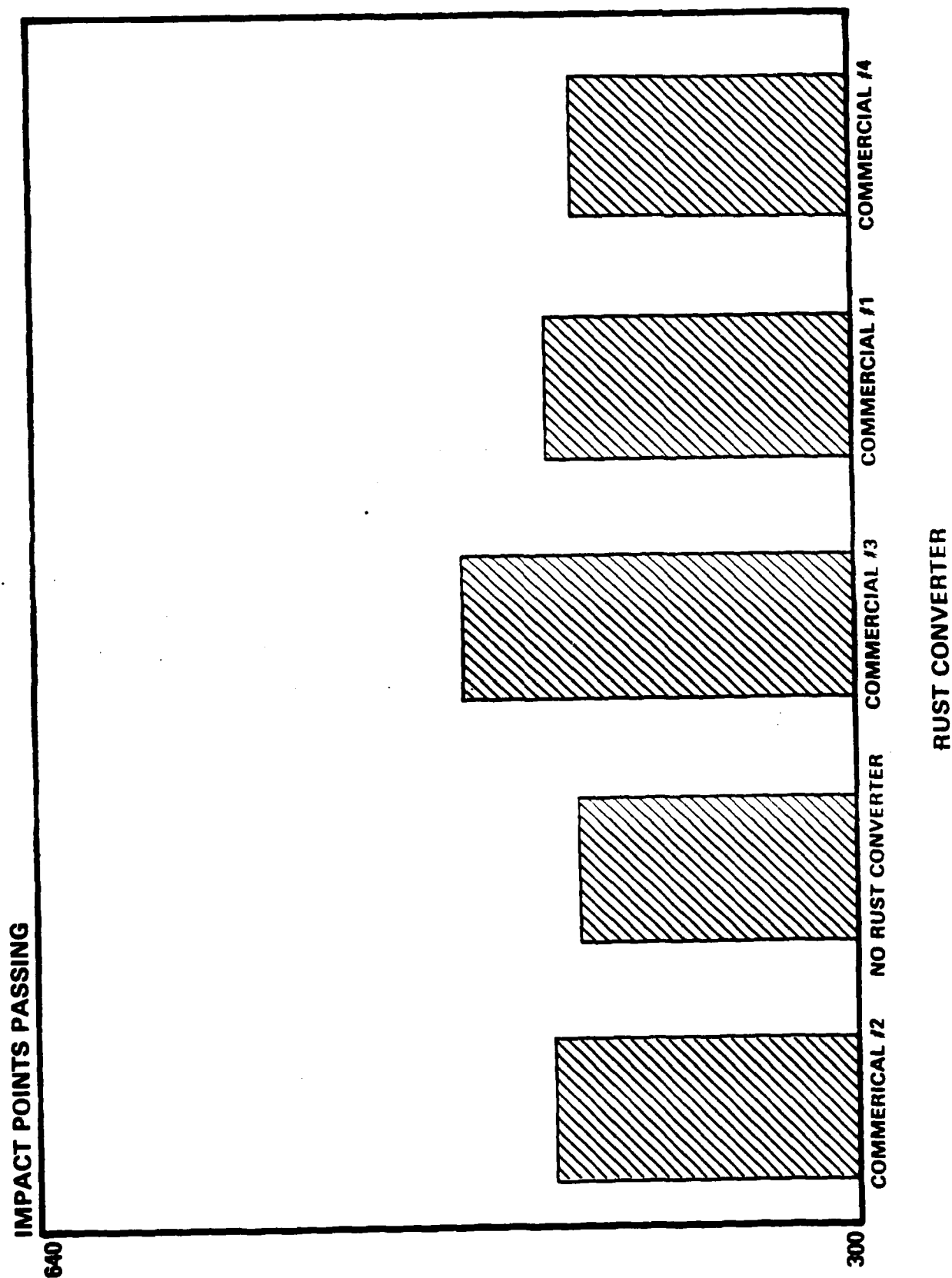


Figure 8. Reverse Impact Resistance—Field Pre-corrosion

Laboratory pre-corroded panels

1. Commercial #1
2. Commercial #2
3. Commercial #4
4. Commercial #3
5. No rust converter

Fielded pre-corroded panels

1. Commercial #3
2. Commercial #1
Commercial #2
4. No rust converter
Commercial #4

In this comparison, Commercial #3 showed a drastic difference in performance when tested over field pre-corrosion and laboratory pre-corrosion in the salt spray. It appeared to last longer than the others over the uniform corrosion found in the field. Note the alteration of Commercial #1's performance—when it converted laboratory pre-corrosion, it clearly out-performed Commercial #2; but over field pre-corrosion, its performance only equaled that of Commercial #2. Taking these differences into consideration, the reverse impact resistance tests yielded no similarities when performed on laboratory and field pre-corrosion.

SECTION V. FLORIDA TESTING

Testing in Florida was carried out in conjunction with the gravelometer test. The procedures followed in the cyclic gravelometer/salt spray test were similar to those followed in the laboratory with the following exceptions: the exposure was in Florida rather than the salt fog cabinet, and the rust converter, Commercial #4, was not evaluated in Florida.

As with the cyclic gravelometer/salt spray testing, the panels for the Florida exposures were prepared, cured, and cooled to 10° below the test temperature of -20°F to allow for a 10-second warm up period from the cold temperature chamber to the gravelometer. Once the panels reached equilibrium in the cold temperature chamber, the upper half was impinged in the gravelometer according to ASTM D 3170, "*Standard test method for chip resistance of coatings.*" The panels were then evaluated using the same standard. (NOTE: A period of 2 hours was arbitrarily decided upon. ASTM D 3170 recommended at least 1 hour in the cold temperature chamber for the panels to reach equilibrium.)

Following the above procedure, the panels were exposed by Sub-Tropical Testing Service in Miami, Florida. The panels were placed at a 45° angle from the horizontal facing south. They were placed in the racks so the impinged area was at the bottom (refer to Figure 1). This prevented drainage from running down the panel, penetrating underneath the topcoat, and thus damaging the unimpinged lower section.

After a period of 12 months, the top and bottom of the panels were evaluated according to ASTM D 610, "*Standard method of evaluating degree of rusting of painted steel surfaces,*" ASTM D 714, "*Standard method of evaluating degree of blistering of paints,*" and ASTM D 1654, "*Standard method for evaluation of painted or coated specimens subjected to corrosive environments.*" Next, the panels were cooled and impinged with gravel on the lower half. In the final step, the lower section was evaluated according to ASTM D 3170.

Considering the ASTM standard evaluations previously stated, the resulting rust converter performances are shown below and graphed in Figures 9 and 10, respectively.

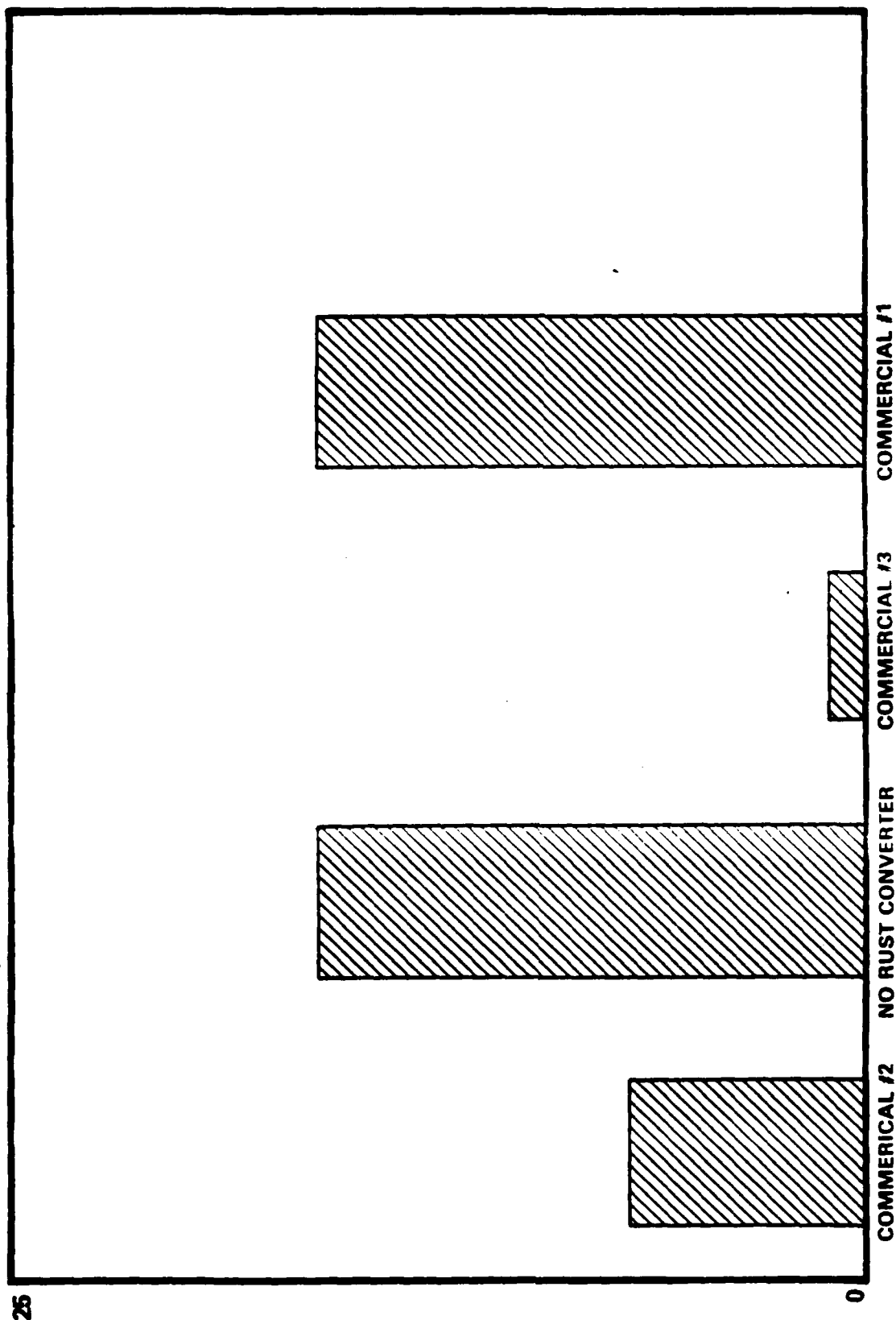
Laboratory pre-corroded panels

1. No rust converter
Commercial #1
3. Commercial #2
4. Commercial #3

Fielded pre-corroded panels

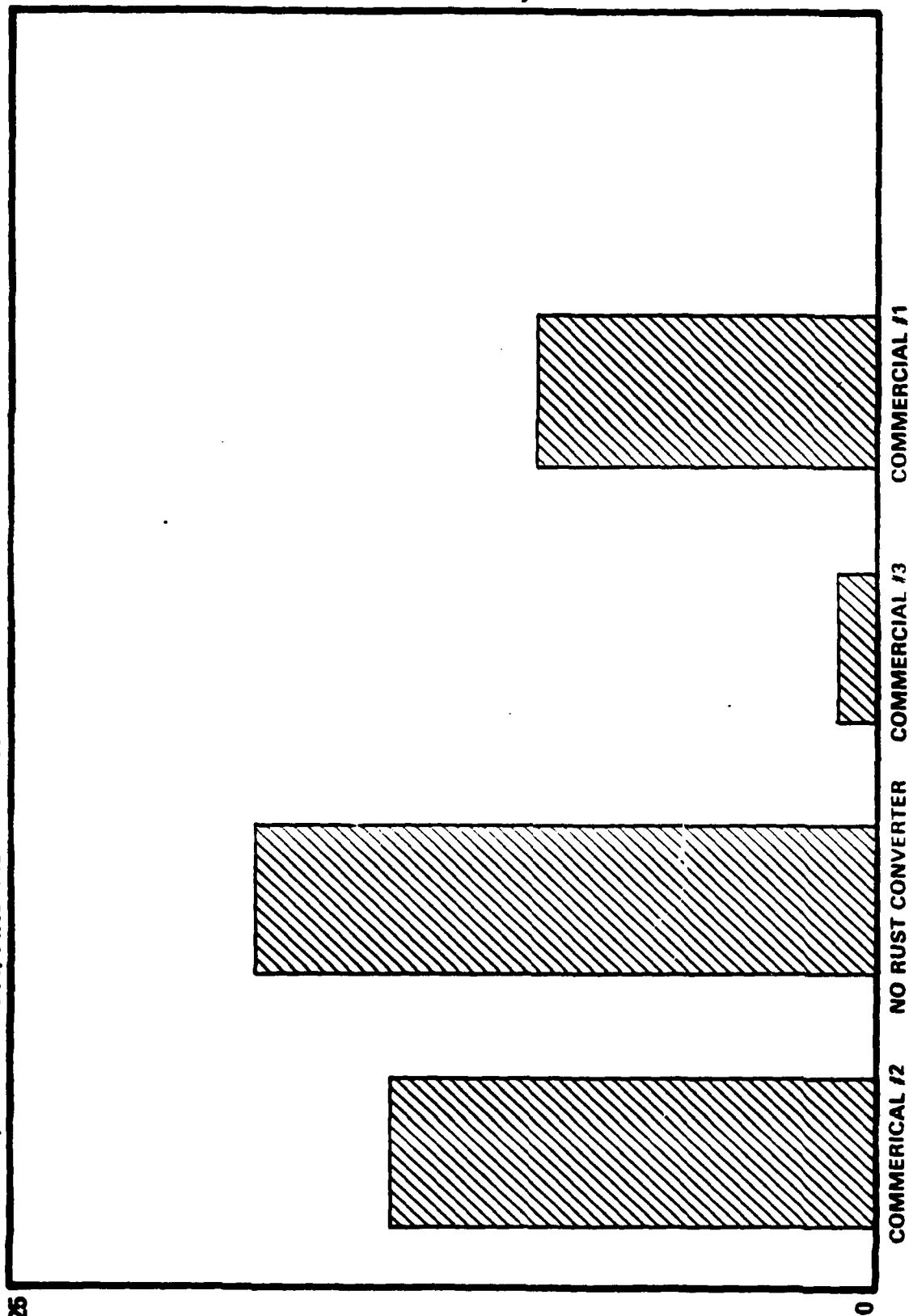
1. No rust converter
2. Commercial #2
3. Commercial #1
4. Commercial #3

These results show some similarity. Commercial #1's performance was clearly affected by the pre-corrosion method. It seemed to do much better in this experiment on laboratory pre-corrosion. Note that the field pre-corroded panels performed better when the intermediate step using the rust converter was eliminated. This would indicate that the rust converters promote corrosion after a period of exposure. Due to economic considerations, the laboratory pre-corroded panels not treated with the rust converter prevailed. The extra expense of using the rust converter was not justified to produce the same results as if it were not used. Except for the difference in the Commercial #1 performance, the Florida testing appeared to produce similar results when testing laboratory and field pre-corroded panels.



RUST CONVERTER

Figure 9. Florida Testing—Laboratory Pre-corrosion



RUST CONVERTER

Figure 10. Florida Testing—Field Pre-corrosion

SECTION VI. FIELD EXPOSURE

Field exposure was conducted in three separate locations: Florida, Hawaii, and Puerto Rico. The exposure in Florida was conducted by Sub-Tropical Testing Service of Miami, Florida. (See Section V.)

The Hawaii and Puerto Rico panels were prepared in the same manner as previous testing discussed in this report. However, unlike previous testing, all panels exposed were pre-corroded for 24 hours in the salt fog cabinets according to ASTM B 117, "Method of salt spray (fog) testing." Field pre-corroded and 120-hour salt spray pre-corroded panels were not considered in Florida. The following rust converters were evaluated:

Hawaii exposure

1. Commercial #3 (annic acid based with latex)
2. Commercial #5 (tannic acid based with latex)
3. Commercial #6 (phosphoric acid based)
4. Commercial #7 (phosphoric acid based)

Puerto Rico exposure

1. Commercial #4 (tannic acid based with latex)
2. Commercial #2 (tannic acid based)
3. Commercial #7 (phosphoric acid based)
4. Commercial #3 (tannic acid based with latex)
5. Commercial #6 (phosphoric acid based)
6. Commercial #5 (tannic acid based with latex)
7. Commercial #8 (tannic acid based with latex)

The panels were oriented at a 45° angle from the horizontal facing south. After a duration of 12 months of exposure in their respective locations, the panels were evaluated according to ASTM D 610, "Standard method of evaluating degree of rusting of painted steel surfaces," ASTM D 714, "Standard method of evaluating degree of blistering of paints," and ASTM D 1654, "Standard method for evaluation of painted or coated specimens subjected to corrosive environments."

According to these ASTM standard evaluations, the resulting rust converter performances are shown below:

Hawaii exposure

1. Commercial #7
2. Commercial #3
3. Commercial #5
4. Commercial #6

Puerto Rico exposure

1. Commercial #2
No rust converter
- Commercial #4
4. Commercial #7
5. Commercial #6
6. Commercial #3
7. Commercial #5
8. Commercial #8

None of the rust converters passed in the Hawaii experiment. A passing mark which was established in previous testing meant receiving a rating of three or better in the ASTM D 610 and ASTM D 1654 standards. Much of the bituminous coating covering the panels had flaked off, exposing the metal surface below.

The information obtained from the Hawaii exposure was disregarded because the panels were lost in transit from Hawaii to Fort Belvoir for a period of time. The duration of the shipment was approximately 4 months. This is significant considering that the wooden boxes used to transport the panels would have become humidity chambers building excessive amounts of heat and moisture. Subsequently, the moisture penetrating underneath the bituminous coating would spread, thus corroding the panels and lifting up the remaining coating.

Therefore, since the Hawaii information has been disregarded, only a comparison between Florida and Puerto Rico exposures can be made. Because only laboratory pre-corrosion was tested in Puerto Rico, it will only be considered against the laboratory pre-corrosion results of the Florida exposure. These results are shown below for the sake of convenience:

Florida exposure (laboratory pre-corroded panels)

1. No rust converter
Commercial #1
3. Commercial #2
4. Commercial #3

In the Florida exposure, the phosphoric acid based rust converter, Commercial #1, did much better than the tannic acid based, Commercial #2. This was not the case, however, in the Puerto Rico exposure. The tannic acid based rust converters, namely, Commercial #2 and Commercial #4, performed better than the phosphoric acid based rust converters, Commercial #3 and Commercial #6. Due to this inconsistency, no real similarity in the two exposures could be found.

SECTION VII. CONCLUSIONS AND RECOMMENDATIONS

The evaluations discussed in this report were undertaken in order to develop a rust converter suitable for military applications. Each particular experiment was performed on both laboratory and field pre-corrosion. The humidity test and the Florida exposure were the only evaluations in which the performances of the rust converters remained the same for both of these pre-corrosion techniques. In all of the remaining evaluations, the performance of the rust converters depended upon the type of pre-corrosion. The pre-corrosion produced in the salt spray chamber was different from that which occurred in the field. The field pre-corrosion was more uniform and showed no streaks as the salt sprayed panels did when the salt water accumulated and ran down the panel. The results from this experimentation showed that the salt spray should not be used as a pre-corrosion technique. Therefore, more time and effort must be placed on developing a pre-corrosion technique which cycles between wet and dry periods, while introducing other parameters, such as ultraviolet light found in the field.

Evaluations on the panels also determined that the currently available rust converters actually accelerated corrosion after a period of time. The majority of the results proved that the bituminous coating directly over the pre-corrosion performed better than using the rust converter as an intermediate step. More research will be needed to formulate a rust converter with properties capable of withstanding harsh military environments.

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